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GEOLOGY, SOILS, AND HYDROGEOLOGY OF VOLO BOG AND VICINITY, LAKE COUNTY, ILLINOIS

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ILLINOIS STATE GEOLOGICAL SURVEY

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INTRODUCTION

Volo Bog, a sphagnum bog in northwestern Lake County, received considerable publicity in the spring of 1970 when plans for a large suburban development in its immediate vicinity created conflict between conservationists and land developers. The problems of preserving unique natural lands, particularly in such rapidly growing areas as Lake County, Illinois, are well known to conservationists. Conversely, desirable areas for developments such as subdivisions, golf courses, and areas suitable for extraction of resources or disposal of solid waste are frequently difficult to obtain once the proposed use is known. A history of the conflict over Volo Bog from the point of view of a conservationist has been presented by Beecher (1970).

In cooperation with the Illinois Nature Preserves Commission and a private consulting firm retained by the developers, the Illinois State Geological Survey and the Soil Conservation Service undertook a study of the physical setting of Volo Bog to secure information on the possible effects that construction of subdivisions, shopping centers, and a golf course, in and immediately adjacent to Volo Bog Basin, might have on the hydrologic regime of the area and on the over-all ecological balance of the bog proper. This report summarizes the principal findings of that study.

While this report was in final stages of prepublication review, John Schwegman of the Illinois Department of Conservation brought to our attention the existence of a drainage tile that apparently drained Volo Bog Basin northwestward into Brandenburg Lake Basin. He noted that at the time he visited the area during a summer a few years ago this drain was flowing a sizeable quantity

* Soil Conservation Service, U. S. Department of Agriculture.

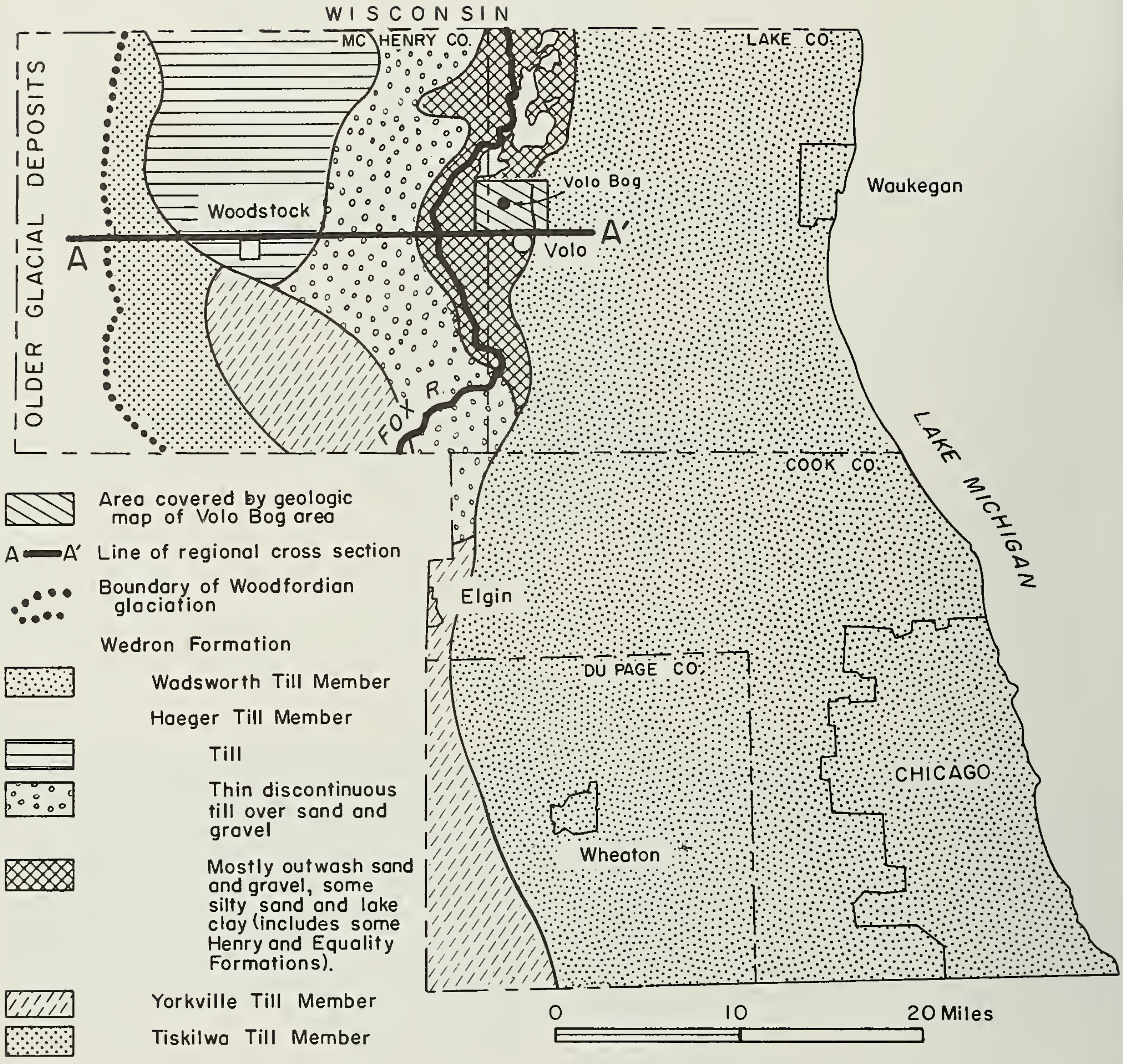

Fig. 1 - Location of Volo Bog, generalized boundaries of regional geologic units, and line of regional cross section.

of water. Although we do not think that the presence of this drain radically affects the interpretations in this report, it should be investigated during any future study.

Volo Bog, originally named Sayer Bog (Waterman, 1926, p. 262), occupies about a quarter of Section 28, T. 45 N., R. 9 E., Lake County, about 1½ miles northwest of the town of Volo and just east of the McHenry County line (fig. 1). The bog is in the late stages of lake filling; only a small area of open water remains in the center, and it is surrounded by a floating mat of sedge and sphagnum moss. As no other bogs in Illinois have open-water ponds, Volo Bog presents a unique opportunity to view the entire sequence of vegetal encroachment in a bog that has been developing since the melting of the last continental glaciers. The bog has been used for more than 40 years as an outdoor botanical laboratory by students and scientists from the University of Illinois, Northwestern University, the Chicago Academy of Sciences, and many other universities, colleges, and scientific organizations.

Volo Bog and several other bogs in northern Illinois were first described by Waterman of Northwestern University (1921). He described the topography, the surficial deposits, the acidity of the water in the bog, and the bog flora. In 1926 Waterman described in detail the environmental factors that caused the bog to develop, including water levels, temperature, acidity of water, and topographic slopes. The stratigraphy and pollen analyses of the organic materials within the bog were reported by Artist (1936). A summary of the flora of the bog has been given by Evers (1963a, 1963b). As part of the recent series of studies on the bog, Arnold (1969), Field Representative of the Illinois Nature Preserves Commission, made depth probings, took peat samples, and prepared cross sections of the bog. Data from Arnold's unpublished technical report are referred to in this report.

Acknowledgments

We thank Dr. W. J. Beecher, Director of the Chicago Academy of Sciences, for his helpful discussion of the setting and problems of Volo Bog, and K.V. Fiske, former Executive Director of the Northeastern Illinois Natural Resources Service Center, for his interest and counsel. We also are indebted to Robert Sasman, Illinois State Water Survey, who provided precipitation records from the Water Survey's near-by Crystal Lake recording station.

PHYSICAL SETTING

Regional Geology

The geologic materials of the region, the soils developed on these materials, and the water present within the materials and soils and as surface water, are the physical elements that make up Volo Bog.

The present landscape in western Lake County and eastern McHenry County has been shaped principally by the activity of the continental glaciers that invaded northeastern Illinois numerous times in the past several hundred thousand years. Most significant, however, were the pulsating advances of the last glacier that entered the region about 23,000 years ago and began its final stages of melting about 12,000 years ago. It is to these debris-laden glaciers that Volo Bog owes its existence. The melting of the ice freed the debris, distributing the various types of deposits and shaping the landscape in essentially its present form.

Physiographically, Volo Bog is within the Wheaton Morainal Country of the Great Lakes Section of the Central Lowland Province of the United

States (Leighton, Ekblaw, and Horberg, 1948). The Wheaton Morainal Country is characterized by rather rugged glacial topography with numerous morainal ridges and many lakes and swamps. Leighton (1925) concluded that drainage from the ice sheet in this part of the state was much greater than in the rest of Illinois. Considerable amounts of washed sand and gravel were therefore deposited. He suggested that the many lake basins and other depressions in the region must have been formed by the melting of large blocks of ice that had been buried by sand and gravel. Leighton, Ekblaw, and Horberg (1948) affirmed that the large basins now occupied by Fox Lake and its associated lakes were formed in this manner.

The glacial moraines, the other principal features of the Wheaton Morainal Country, are ridges of unsorted debris (called till) that were formed at the front of the glacier when the ice melted. The glacial till is generally relatively thick in the moraines, but it is usually thinner behind the moraines, in most places no more than 10 or 20 feet thick. Most of the moraines of eastern McHenry County and western Lake County are mapped as part of the Valparaiso Morainic System, which extends from the Wisconsin line to the Indiana line, roughly paralleling Lake Michigan (Willman, 1971, p. 47).

The total thickness of glacial deposits of this region reaches a maximum of 400 feet, although the average is probably closer to 200 feet. They rest on bedrock consisting of Silurian and Ordovician dolomites and shales.

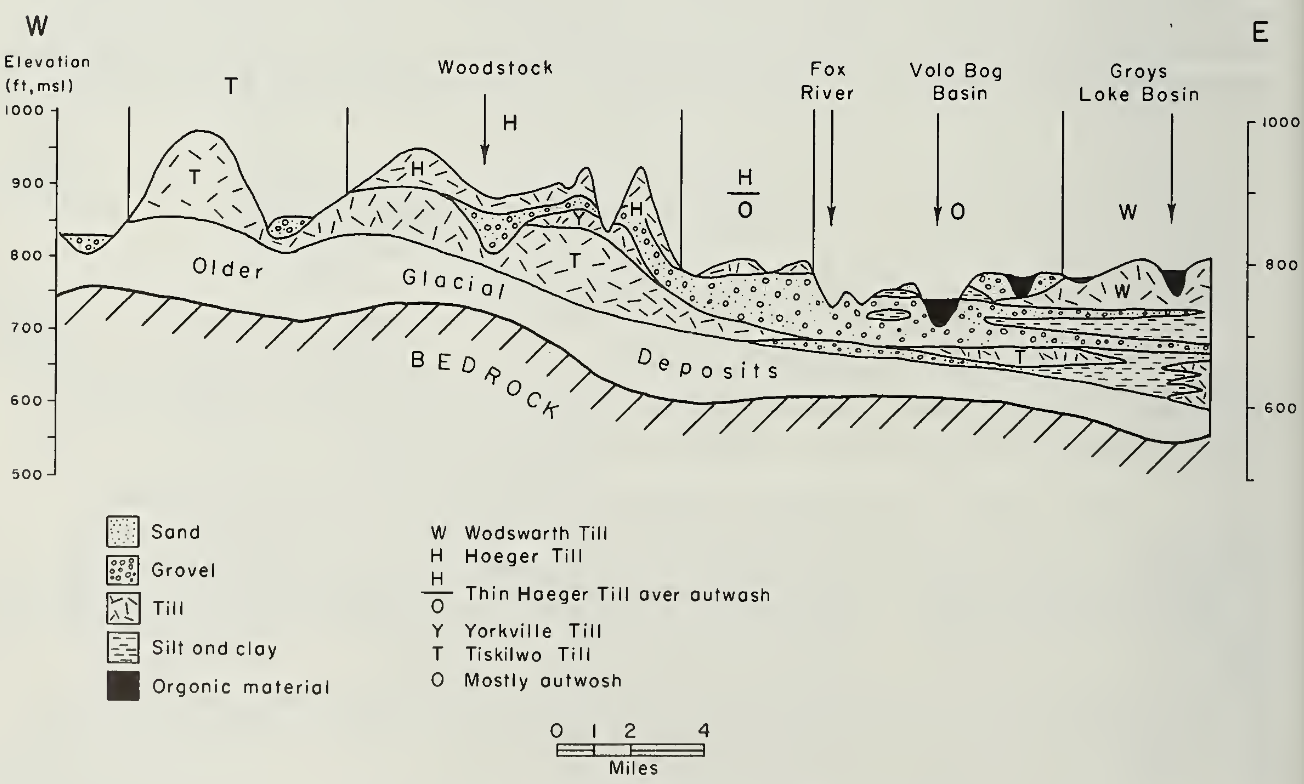

Fig. 2 - Regional cross section of glacial drift.

Records from water-well drilling in the region show that valleys were carved into the bedrock and then later filled with glacial debris.

Several distinct glacial tills, deposited by different pulses of the last Wisconsinan glacier (the Woodfordian) have been identified in the region (Kempton and Hackett, 1968; Frye et al., 1969; Willman and Frye, 1970; and Willman, 1971). The distribution and stratigraphic position of these tills are shown in figures 1 and 2. The lowermost till (Tiskilwa Till Member) rests locally on an organic deposit that has been dated as being 23,000 years old by the radiocarbon method. The Tiskilwa, a distinctive reddish brown till, is overlain by the gray Yorkville Till Member. Both tills are well exposed in McHenry and Kane Counties. The Tiskilwa is by far the thickest till of the region (fig. 2), averaging close to 100 feet thick in McHenry County and reaching well over 200 feet in the northwestern part of the county. The tills thin rapidly eastward and have not been identified with certainty in most of Lake County. Very little sand and gravel outwash is associated with either till.

The tills and other related deposits of the last two glacial pulses of the Woodfordian Substage are most significant to the development of Volo Bog. During the earlier of these advances, about 14,000 years ago, sandy, gravelly till (Haeger Till Member) and considerable quantities of sand and gravel were deposited in central and eastern McHenry County and western Lake County, and numerous partially buried blocks of ice lingered after the bulk of the glacier had melted. The last glacier to reach the Volo Bog area advanced to within about a mile of its eastern border and deposited a gray clayey till (Wadsworth Till Member) that covered most of Lake County and Cook and Du Page Counties to the south. In some places in western Lake County, the Wadsworth Till directly overlies the outwash from the glacier that deposited the Haeger Till.

Geology of Volo Bog Area

The generalized geologic map (fig. 3) of near-surface deposits in the 12 square miles around Volo Bog is based on mapped soils, subsurface geologic investigation, and field checks. The oldest surface deposit shown on the map is a coarse-textured sand and gravel outwash from the glacier that deposited the Haeger Till. It is therefore included in the Haeger Till Member (Wedron Formation) in this report, even though very little till has been reported overlying the outwash in this area. Locally the outwash is more than 80 feet thick. In this area it reaches a maximum elevation of approximately 780 feet, although more commonly it is no more than 740 or 750 feet in elevation.

Overlying the Haeger Member is a yellowish gray to gray clay or silty clay interpreted as having been deposited in a lake named Lake Wauconda by Powers and Ekblaw (1940). Where lake clays such as this are the surface deposit, they are mapped as part of the Equality Formation (Willman and Frye, 1970, p. 72-74), as they are in figure 3. However, where they lie below the Henry Formation they are included in the Wedron Formation (fig. 4). This lake clay is generally rather uniform, occasionally faintly bedded; but as most of it has a very high clay content it has a blocky structure where it has been

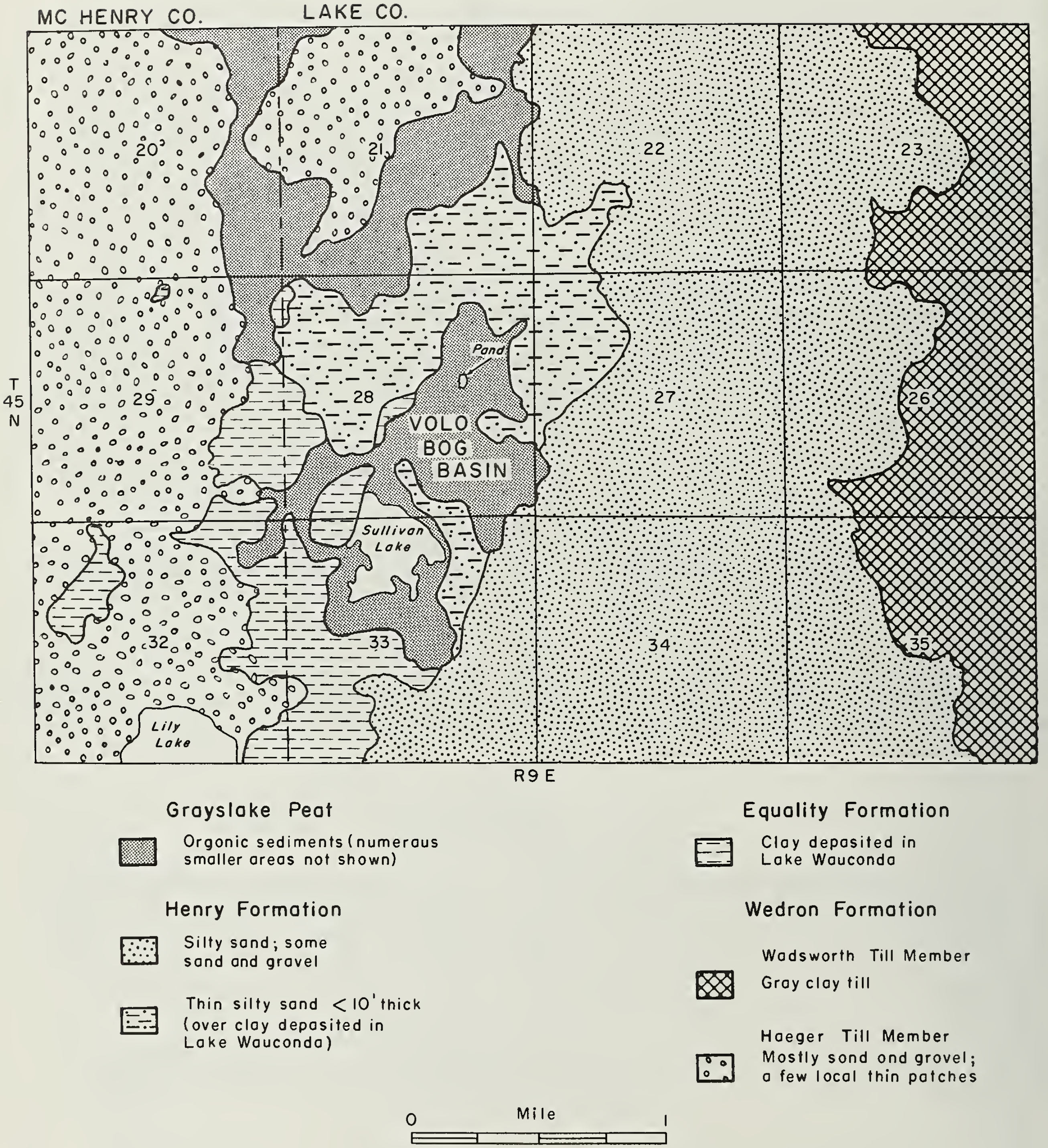

Fig. 3 - Surficial geologic map of Volo Bog area.

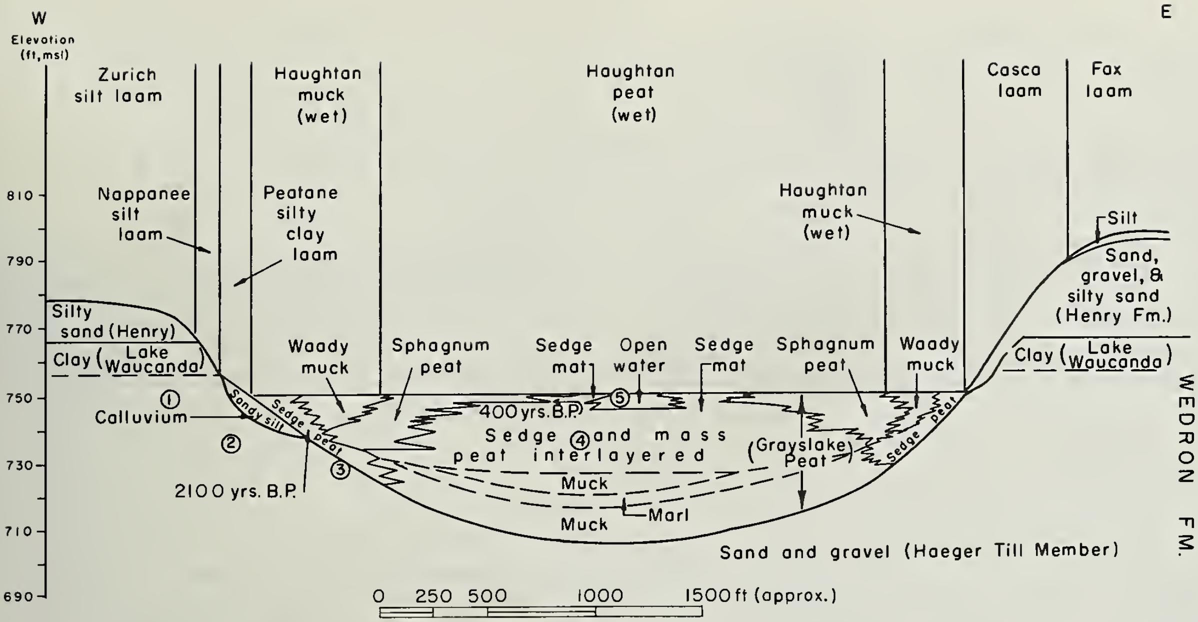

Fig. 4 - Generalized cross section through Volo Bog Basin showing relations of geology, soils, and vegetation. Sampling points for water and radiocarbon analyses (modified in part from Artist, 1936) are indicated by numbers in circles and are explained in table 3.

seen in exposures. It is normally found to cap the sand and gravel of the Haeger Member at elevations somewhere between 750 and 765 feet (fig. 4). It has not been observed to be more than 10 to 15 feet thick.

The next younger deposit, the Henry Formation, is a silty sand or, locally, sand and gravel that lies directly on top of the clay deposited in Lake Wauconda in the vicinity of Volo Bog Basin. Where present west and north of the basin, the Henry Formation is almost always a fine, silty sand, generally 10 feet thick (fig. 3). To the east of Volo Bog Basin, it is thicker than 10 feet, for the most part, and is locally more sandy and gravelly. The deposits included in the Henry Formation are interpreted as outwash from the glacier that deposited the Wadsworth Till to the east (fig. 4).

The Wadsworth Till is a gray, clayey till quite distinct from the sandy, gravelly till of the Haeger Member. Its surface is characterized by a hummocky, irregular surface, capped locally by sands, gravels, silts, and organic deposits. It may extend under the Henry Formation for at least a short distance westward.

The organic deposits that fill or partly fill the depressions left by late-melting blocks of glacier ice in the sand and gravel throughout the area and also fill the irregularities in the surface of the Wadsworth Till are collectively called the Grayslake Peat (Willman and Frye, 1970). These deposits range in thickness from a few feet to more than 30 feet (Artist, 1936). Thin local wedges of colluvium are included in the Grayslake Peat. They have eroded from the sides of the basin and may in part underlie the organic deposits.

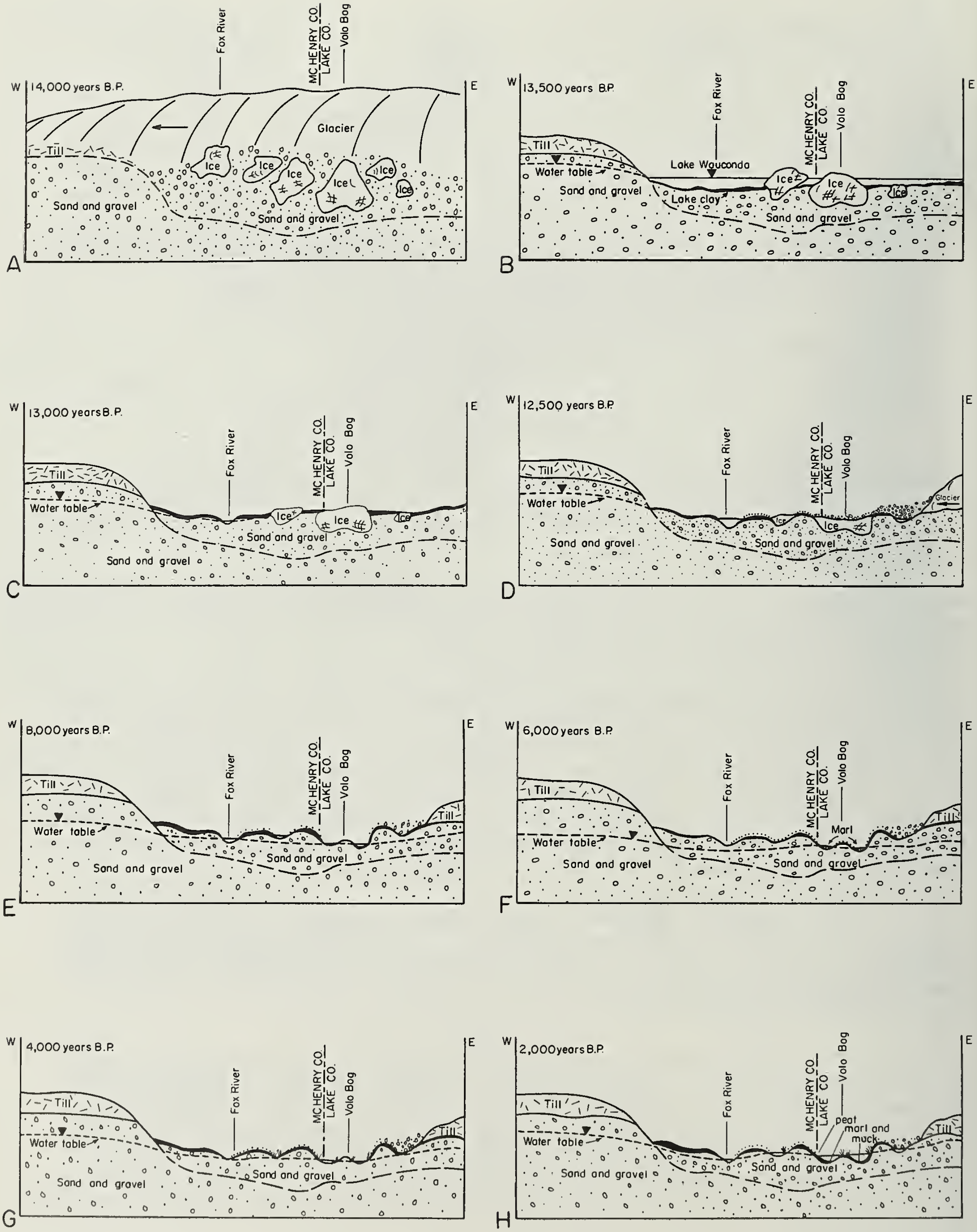
W
14,000 years B.P.
Fox River
MC HENRY CO.
LAKE CO.
Volo Bog
E
Glacier
Till
Ice
Sand and gravel
A
13,500 years B.P.
Lake Wauconda
Water table
Lake clay
B
13,000 years B.P.
C
12,500 years B.P.
D
8,000 years B.P.
E
6,000 years B.P.
Marl
F
4,000 years B.P.
G
2,000 years B.P.
peat
marl and muck
H

Fig. 5 - Principal events in geologic history of Volo Bog.

A. Glacier advances over proglacial sand and gravel, depositing thin till (Haeger) and sand and gravel with incorporated ice blocks.

B. Ice block near Algonquin forms dam and creates Lake Wauconda; ice blocks become islands in lake. Clay is deposited in lake over sand and gravel.

C. Ice block dam breaks, and Lake Wauconda drains via the Fox River.

D. Wadsworth glacier advances from east and deposits sand and gravel over clay.

E. Area drains. Deposition of loess on sand and gravel. Colluviation begins.

F. Area has drained to maximum water table decline. Marl forms in shallow lakes and organic debris accumulates. Upland depressions partly fill with colluvium.

G. Water table and lake levels rise. Reed and sedge growth on the periphery of the lakes is periodically drowned by rising water. Organic debris accumulates on top of marl and at sides of lakes.

H. Water table rises to within 5 feet of present elevation. Reed and sedge peat forms along lake shores. Bog fills with organic debris.

In the deepest part of Volo Bog, several feet of silt rich in organic material (muck) and interbedded marl has been reported; it is overlain by interbedded sedge and moss peat (fig. 4). A somewhat similar situation has been recorded in Grays Lake Basin (Ogden and Hay, 1964, p. 344-345) about 8 miles to the east of Volo Bog, the principal difference being that deposits in that basin probably bottom on the Wadsworth Till. A radiocarbon date from marl in Grays Lake Basin has been reported as 6539 ± 97 years before present (B.P.) (OWU-34)* at a depth of 9.92 to 10.08 meters (32.7 to 33.2 ft). Another sample of stiff clay rich in organic matter from a depth of 8.7 to 8.82 meters (28.7 ft) in Grays Lake was dated as 4003 ± 97 years B.P. (OWU-33). A radiocarbon date from near the edge of Volo Bog, 5 feet from the surface at the base of the peat and directly above sand and gravel, has been determined as 2100 ± 200 years B.P. (ISGS-49)*. In addition, a date from decayed sphagnum peat at the base of the sphagnum mat near the center of Volo Bog has been dated at 460 ± 310 radiocarbon years B.P. (ISGS-50).

GEOLOGIC HISTORY

Although events prior to the advance of the Woodfordian glacier have some significance for the regional or over-all setting for Volo Bog, their influence is considered too indirect to be discussed in detail here. Suffice it to say that just prior to the advance of the first Woodfordian glacier, woody organic silt (Robein Silt) and soil formed for approximately 6000 years (Farmdalian Substage). The youngest date from the top of the Robein Silt in northeastern Illinois has been established at 23,000 years B.P. (I-2783)* from a boring in northwestern Cook County about 20 miles south of Volo Bog. This date indicates the beginning of the Woodfordian glaciation, which later produced the conditions for the formation of Volo Bog.

After the deposition of the Tiskilwa and Yorkville Tills, the general topography had been developed for deposition of the Haeger Till (including the associated outwash) and the subsequent Wadsworth Till (fig. 2). Figure 5 shows

* Abbreviations following radiocarbon dates refer to the laboratories at which dates were assigned: OWU = Ohio Wesleyan University, ISGS = Illinois State Geological Survey, and I = Isotopes, Inc.

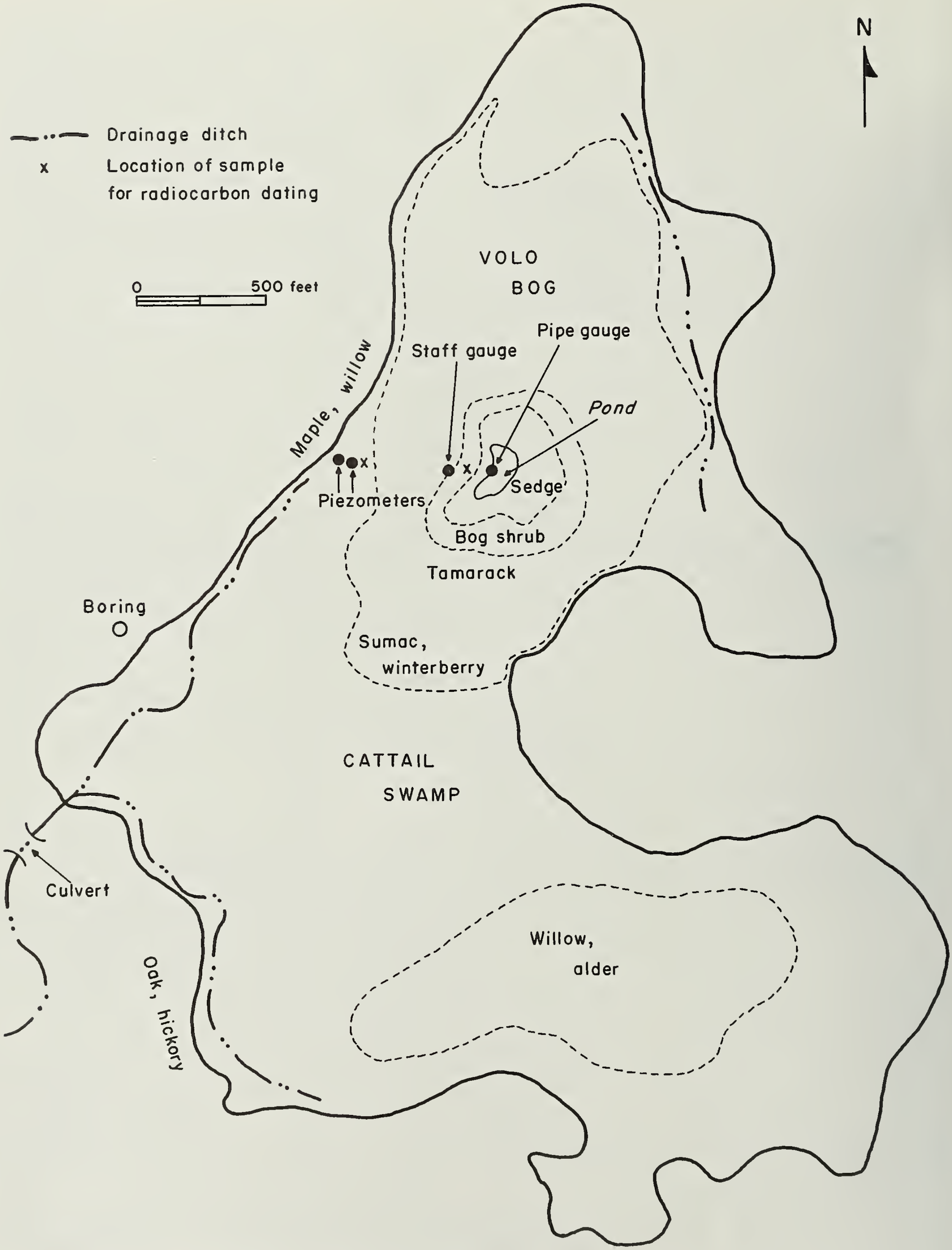

Fig. 6 - Volo Bog Basin, its probable vegetation zones (after Arnold, 1969), and hydrologic data points.

diagrammatically the probable sequence of events initiated by the advance of the Haeger glacier (fig. 5A) into a lowland along the Fox River about 14,000 years ago.

The Haeger ice probably stagnated once it had reached into southeastern McHenry County, leaving ice blocks in the lower reaches of the Fox River Valley that formed a dam, creating Lake Wauconda (fig. 5B) (Powers and Ekblaw, 1940). As the elevations of the top of the clay deposited in Lake Wauconda (figs. 3 and 4) are approximately 765 or 770 feet, the lake level must have been somewhat higher, possibly as much as 800 feet. The lake clay was deposited only locally, principally on the sand and gravel upland areas adjacent to the present depressions. Because the area east of the Fox Valley is generally 800 feet or less in elevation, the eastern margin of Lake Wauconda may have been formed by the advancing Wadsworth glacier.

By the time the Wadsworth glacier reached its most western position just east of Volo Bog, the ice dam near Algonquin in the Fox Valley had apparently broken and Lake Wauconda was drained (fig. 5C). Shortly thereafter, sands, gravels, and silty sands from the melting glacier to the east were deposited over the lake clay and around the melting ice blocks in the Fox Valley (fig. 5D). This final glacial advance probably occurred approximately 12,500 years B.P. It deposited the Wadsworth Till and apparently melted rather rapidly, possibly about 12,000 years ago. When the glacier melted, the area in the southern part of the Lake Michigan Basin filled with meltwater to form glacial Lake Chicago. Dates from beach ridges related to Lake Chicago have been reported as 12,650 and 12,200 years B.P. With the melting of the last glacier from the region, the temperature continued to rise, and the last ice blocks probably had melted by 10,000 years B.P. They left numerous depressions containing lakes, upon which vegetation was beginning to encroach (fig. 5E).

However, as the temperature continued to rise and drier conditions prevailed about 6000 years B.P., water levels stood much lower in the lakes (fig. 5F). In fact, many may have dried up. It was at this time that the organic silt and the marl were deposited at the lake bottoms. A date (6539 B.P.) on marl from near-by Grays Lake supports this interpretation. Following the drier period, precipitation increased. The additional rainfall raised regional water levels, vegetation grew rapidly, and peat began to form in the lakes. As the water levels in the lakes rose, the peripheral vegetation was periodically flooded and killed. The dead vegetation sank to the bottom, and new vegetation encroached still farther into the lakes. That the filling was nearly continuous in Volo and near-by bogs from 6000 B.P. to the present is suggested by the dates 6539 and 4003 years B.P. from Grays Lake and by the date 2100 years B.P. from the edge of Volo Bog at approximately the highest level of peat formation (figs. 5G, H). Figure 6 shows the approximate areas covered by the principal types of vegetation at the present stage of bog development.

SOILS

As soon as each of the materials in the Volo Bog region was deposited and exposed to the atmosphere, soil formation and profile development began. In

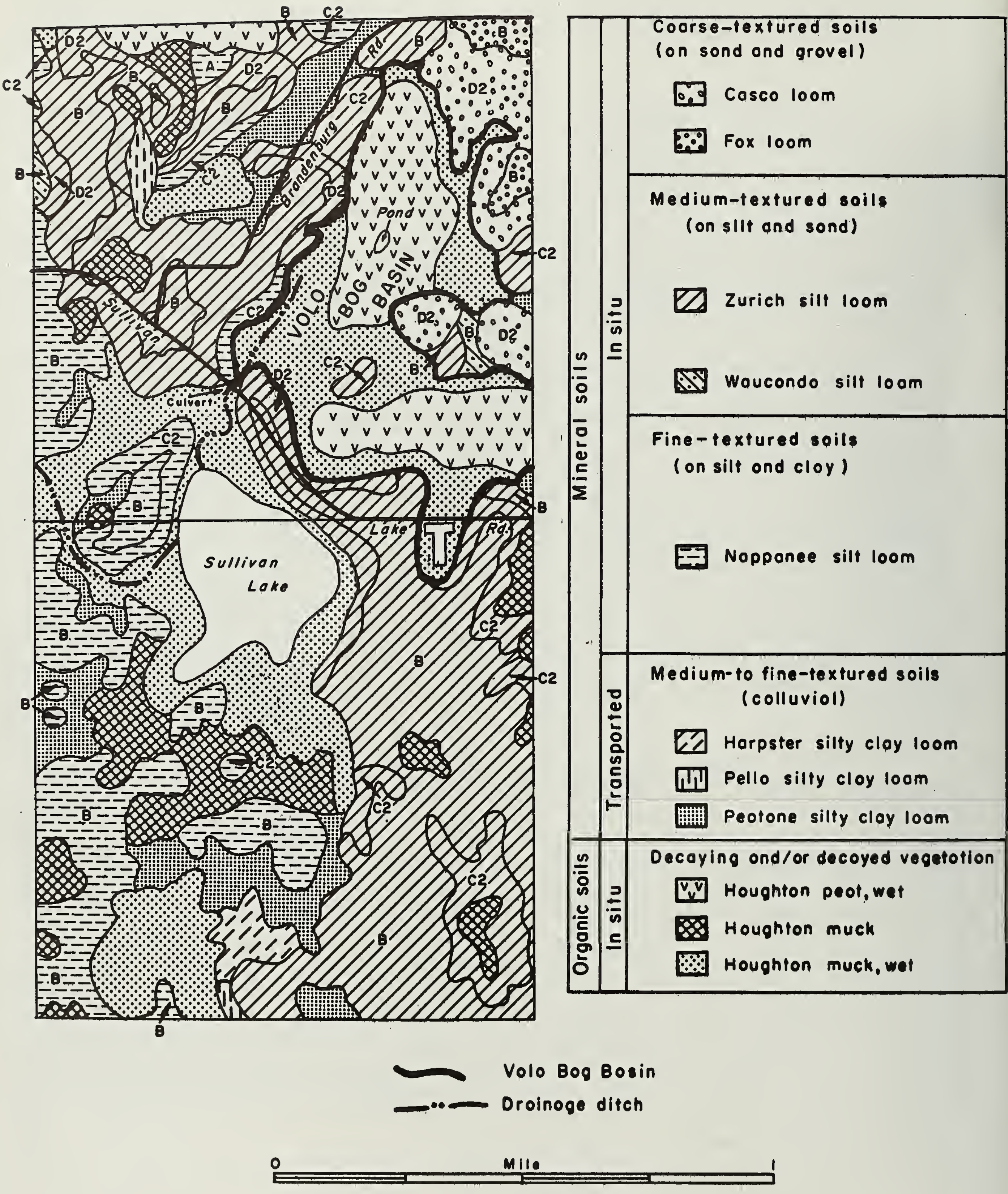

Fig. 7 - Soil-parent material map of Volo Bog Basin and sourrounding area.

this area the most significant soil-forming factors are topography, vegetation, and parent materials. The effects of climate and time are similar for all soils developed in the area and therefore do not account for the differences between soils. Figure 7 is the soil — parent material map of much of the Volo Bog Basin and the adjacent uplands. The soil names and slope characteristics are given in table 1. The relation of the soils to the geology is shown in figure 4.

The topography of the area ranges from nearly level on the uplands and depressional areas to steep slopes, and it not only affects soil development but also determines the kinds of materials exposed for soil development. The occurrence of colluviated (transported) material is directly related to the presence of slopes, the erodability of the materials upslope, and the amount and nature of vegetation covering the uplands and slopes.

The native vegetation of the area during soil development was dominantly oak-hickory forest on the better drained uplands and aquatic grasses and sedges on the poorly drained lowlands. Each type of vegetation gives an identifiable characteristic to the soil profile.

Soils in the Volo Bog area are significantly affected by the parent material in which they have developed. Upland soils are mineral soils formed

TABLE 1—PARENT MATERIALS, SOIL NAMES, AND SOIL SLOPE CHARACTERISTICS*

Type of soil	Parent material	Soil name	Slope (%)	Erosion
Mineral soils	Coarse-textured sand and gravel (outwash)	Casco loam (D2)	7-12	Eroded
		Fox loam (B)	2-4	
	Medium-textured sand and silt (outwash)	Zurich silt loam (B)	2-4	
		Zurich silt loam (C2)	4-7	Eroded
		Zurich silt loam (D2)	7-12	Eroded
		Wauconda silt loam (B)	2-4	
	Fine-textured silt and clay (lacustrine)	Nappanee silt loam (A)	0-2	
		Nappanee silt loam (B)	2-4	
		Nappanee silt loam (C2)	4-7	Eroded
	Silt, sand, and clay (colluvial)	Harpster silty clay loam		On lower slopes and in small depressions; transported during soil formations
		Pella silty clay loam		
		Peotone silty clay loam		
Organic soils	Principally decayed vegetation	Houghton peat, wet		Depressions
		Houghton muck		
		Houghton muck, wet		

* See figure 7.

from material deposited at the time of the last glaciation and developed in place (in situ). Colluvial soils were developed during transport downslope and are usually found at or near the base of slopes. The low-lying marshes and bogs of the lake basin areas have partially or completely filled with organic materials since the glaciers melted and consequently have organic soils. All of the soils have some morphological characteristics or physical properties related to the parent material from which they formed and some related to the other soil-forming factors. The characteristics and properties of different soils inherited from the same parent materials are the same, even though other soil-forming factors add other characteristics. Therefore, a whole group of soils can be associated with each parent material (fig. 7). Such groups of soils can be used in mapping geologic materials (McComas, Hinkley, and Kempton, 1969) and have proved particularly useful in mapping the geology of the Volo Bog area.

The parent material-soil groups of the uplands adjacent to Volo Bog are distinguished on the basis of the texture of the parent materials—coarse (gravel and sand, developed mainly on the Haeger Member), medium (sand and silt, developed mainly on the Henry Formation), and fine (silt and clay, developed principally on the Equality Formation).

The coarse-textured soils are principally Casco loam and Fox loam. Casco loam soils are light colored, well drained soils with very thin, brown, clay loam subsoils. They formed in less than 20 inches of medium-textured material over calcareous sands and gravels. In the immediate vicinity of Volo Bog these soils are locally developed on the sand and gravel phase of the Henry Formation and, to the west, on the sand and gravel phase of the Haeger.

The medium-textured soils are Zurich silt loam and Wauconda silt loam. The Zurich silt loam soils are light colored and well drained, with brown, silty clay loam subsoils. They formed in 20 to 40 inches of silty material over medium-textured, calcareous, stratified silts and sands. The Wauconda silt loam soils are moderately dark and somewhat poorly drained, with grayish brown, mottled, silty clay loam subsoils. They formed in 20 to 40 inches of silty material over calcareous stratified silts and sands.

The fine-textured soil is Nappanee silt loam, which is a light colored, somewhat poorly drained soil with a grayish brown, mottled, silty clay subsoil. It formed in less than 20 inches of silty material over silty clay lacustrine deposits.

Associated low-lying, poorly drained, colluvial mineral soils are principally Peotone silty clay loam, Pella silty clay loam, and Harpster silty clay loam. They have dark-colored surface layers and gray subsoils. They formed locally in stratified colluvial materials.

Soils formed in the organic materials are in the low-lying marsh and bog areas. The organic soils formed from the reeds and sedges still show the original plant materials in various stages of decomposition. Organic soils are classified on the basis of the decomposition of the materials. The soils with the least decomposed materials are called peat, and soils with the most decomposed organic material are called muck; the peat soil in the Volo Bog area is Houghton peat, and the mucks are Houghton muck.

Detailed soil descriptions and soil classifications are given in the Lake County soil report (Paschke and Alexander, 1970). A few minor modifications of those soil classifications were made in figure 7, based on observations made during this study.

HYDROGEOLOGY

For the purpose of describing the hydrogeology, the lowland area in the east half of Section 28, consisting of Volo Bog and Cattail Swamp, is called Volo Bog Basin (figs. 6, 7, and 8). The hydrogeologic investigation involves the study of surface water, evapotranspiration, and ground water, and their interaction with the organic materials in the basin.

Surface Water

Volo Bog, near-by Wilson Bog to the northwest, and other adjacent lowland peat swamps along the McHenry—Lake County line are poorly drained, primarily because their gradients for surface-water flow are low, surrounding surface materials are very permeable, and the retentive capacity of organic materials in the basins is high. The natural direction of the flow of surface water from Volo Bog prior to arrival of the early settlers was probably northwestward into Brandenburg Lake or southwestward toward Sullivan Lake, then northwestward to Pistakee Bay (fig. 8). At present, Volo Bog Basin drains southward through man-made ditches and a culvert to Sullivan Lake, which in turn drains to Pistakee Bay through man-made Lily Lake drain.

Surface water enters the basin by direct precipitation, by winter runoff over immediately adjacent frozen ground, and occasionally by sheet runoff in the summer during intense rainfall. Because the permeability of the upland sand and gravel is high, most of the rain that falls on unfrozen ground infiltrates, although some of this water is later lost by evapotranspiration. Surface water in the basin is present in an open pond in the center of the bog throughout the year and in small pools on the sphagnum mat in the bog and in the marsh surrounding the bog for most of the year. In July, August, and September, most of the pools are dry. The marsh pools are separated by hummocks of grass and cattails with apparent high hydraulic conductivity, permitting almost free flow between the pools. The drainage ditch through the marsh undoubtedly contributes to the scarcity of water in the marsh in late summer.

The drainage ditches in the basin were probably hand dug by the early settlers in an attempt to drain the swamp for agriculture. The ditches and the drain through to Sullivan Lake were reported by Waterman (1921) in his early observations of the basin. To determine the effect of the discharge through the culvert on water levels in the basin, we monitored the flow weekly from April through August 1970. Discharge velocities were estimated by determining the rate of flow of a partly submerged object through the culvert. These data are qualitative only and are shown in figure 9 to illustrate the relation between precipitation and culvert discharge. The highest estimated discharge was 3.5 cubic feet per second; the lowest was zero.

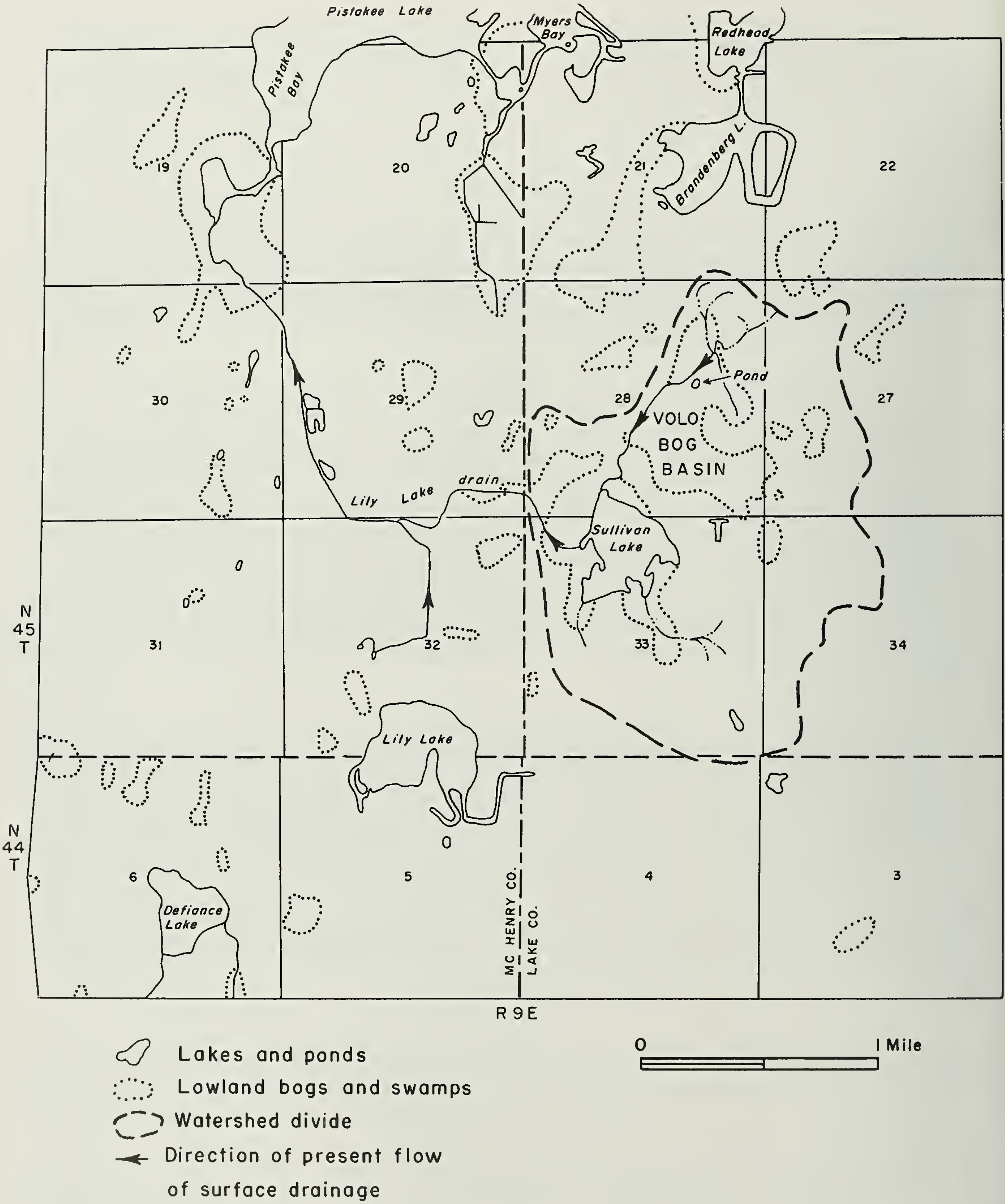

Fig. 8 - Surface drainage of the Volo Bog area.

The rapid increase of discharge in the culvert after rainfall in the spring, followed by rapid decrease, indicates that the materials are saturated in the spring and little further retention takes place. During this season the marsh pools are continually draining to the ditches and providing flow to the culvert. Early in July the culvert ceased flowing, even after heavy rainfall. This suggested that evapotranspiration was keeping up with rainfall and that essentially no ground water left the basin as base flow to the ditch.

Evapotranspiration

Annual precipitation in the Volo Bog area is about 32 inches (Sasman, 1957). Evaporation from near-by Crystal Lake, an open-water lake, is approximately 30 inches per year (Roberts and Stall, 1966). Evapotranspiration at Volo Bog probably exceeds evaporation from Crystal Lake during the summer growing season because of the high transpiration by hydrophytes (plants living wholly or partly in water). However, during the winter season when plants are dormant, evaporation from Volo Bog Basin is probably less than that from Crystal Lake because vegetation in the bog reduces evaporation by sheltering the water from wind and by shading it from the sun (Eisenlohr, 1966). Therefore, the measured evaporation rate at Crystal Lake for a year might approximate the annual evapotranspiration in the Volo Bog Basin. As evapotranspiration during the summer accounts for most of the moisture loss in Volo Bog Basin, the dearth of surface-water outflow from the basin is understandable.

Surface water fluctuations within the bog were monitored at the west edge of the pond (fig. 6) by means of a pipe driven through the sedge mat and the soft organic material into solid material at the base, 39.5 feet below the surface. Pond-level fluctuations were determined by the distance between a reference point on the pipe and the surface of the pond.

The level of the water was measured weekly from May 1 to December 1, 1970. Pond fluctuations to June 15 were less that 2 inches up or down. During this period the culvert under Sullivan Lake Road averaged a flow of about 1 cubic foot per second. From June 15 to July 13, the pond level dropped 3.5 inches and the culvert ceased flowing (fig. 9). Pond levels continued to drop to a maximum total of 9 inches by September 1. The pond level then recovered rapidly to 1.4 inches below the May 18 reading by October 20. This indicates that when the growing season ends, water inflow exceeds outflow. The culvert had begun flowing by October 20 and the pond level had nearly stabilized, indicating that approximated outflow equalled inflow. Some additional recovery of the pond occurs during the winter and spring. These data suggest that the bog operates much as do ground-water fed lakes, such as Crystal Lake.

The sedge mat immediately adjacent to the open pond is about 3 feet thick and is floating. Frequent measurements with the pipe gauge as datum showed that the mat dropped as the water level in the pond dropped. To determine the relation of the water level in the pond to water levels in the organic materials farther away from the open pond, a staff gauge was placed in a pool found in a break in the mat about 30 feet west of the open pond. In this area, the mat was floating on a semifluid mixture of peat and muck. The gauge showed the water level in the pool declined 7 inches between May and September, while the open pond showed a water-level drop of 9 inches (fig. 9). In early September,

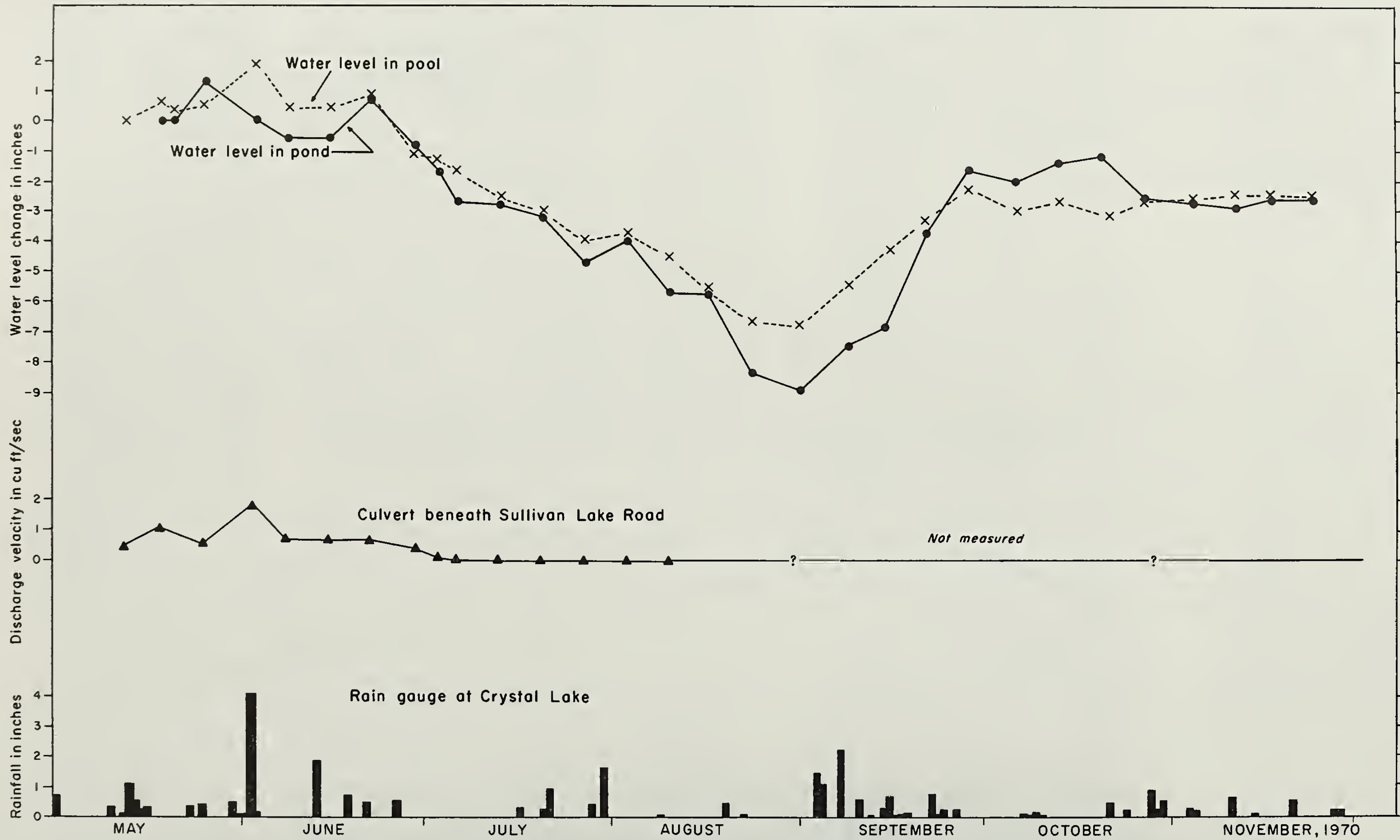

Fig. 9 - Water level fluctuations, culvert discharge, and precipitation in the Volo Bog Basin, May through November, 1970.

water levels in both the open pond and small pool rose to a point about 3 inches below the May datum. In October, the water level in the pond rose about 2 inches above the level in the pool.

Several factors are responsible for the fluctuations in the water levels and for the difference between the pond and pool levels. During June, July, and August, evaporation from the pond surface exceeds evapotranspiration from the vegetated and shaded area of the mat. The water in both mat and organic material flows toward the pond and recharges it. As the water moves out of the semifluid organic material, the mat subsides and compacts. In September, increased precipitation and decreased evapotranspiration causes recovery in water levels in both pond and pool. The reduced permeability of the compacted organic material serves as a temporary dam in October, and the water level in the pond rises above the water level in the pool. By the end of October, the water from the pond has seeped into the organic material and the organic mat rises. In November, the pond water level is lower than that of the pool, and the organic materials supply water to the pond. In general, the flow of ground water from outside the bog is through the organic materials in the bog to the open-water pond in the center of the bog.

Water level measurements in a similar bog were taken by Burns (1905) in the Huron River Valley of Michigan. His data showed that water levels in the sedge zone of a bog varied little, because the mat floated on open water. The system in Volo Bog appears to be quite similar to that observed by Burns in that the mat surface moves up and down with the water level. By analogy with water level fluctuations of Crystal Lake (Sasman, 1957), water level declines in the bog throughout the past 40 years can be estimated as about 3 or 4 feet, although, as no fixed measuring points existed, they have not been observed.

That the hydrophytes are seldom killed when the water level declines can be attributed to two factors. First, sphagnum peats can absorb up to 16 times their weight of water, enough to actually lift the water table above the surrounding land (Stephens, 1955). This water-holding capacity may supply sufficient water to the bog vegetation to allow its survival during periods of low precipitation and low ground-water inflow. Second, when the water level declines in the bog, the bog surface also subsides, so that the water level for the vegetation is thus kept constant.

Ground Water

The vegetation of Volo Bog Basin is supported mainly by ground water—that is, water below the water table. Water enters the ground in recharge areas and moves downward to the water table. It moves laterally below the water table and is discharged to the surface, providing the base flow for streams and the water for permanent swamps, bogs, or lakes. The driving force for its movement is gravity; the direction of movement is a function of pressure.

The recharge area for Volo Bog Basin is the surrounding upland. There water enters the ground and migrates from a point of higher head (pressure) to a point of lower head (the potential gradient) to discharge in the basin. In the recharge area the potential gradient is downward from the water table, whereas in discharge areas the gradient is upward toward the water table. The actual potential gradient is commonly determined by installing small-diameter well points with screened tips, called piezometers, at different depths at the same location. As the piezometers are sealed above the screen, the water level in the piezometer represents the hydraulic head of the stratum at the screened interval.

Two piezometers were installed in Volo Bog Basin about 20 feet from the western edge of the bog, along the plank walk (fig. 6). They were driven to depths of 8.5 and 12.5 feet below the surface into the sand and gravel under the peat. The deeper piezometer on June 15 had a water level of 0.03 feet below ground surface and the shallow piezometer had a water level of 0.49 feet below ground surface, indicating that the potential gradient was upward to the water table, which is at ground surface. Weekly measurements taken up to December 1 confirm the constant upward potential gradient. Therefore, Volo Bog Basin is a ground-water discharge zone and remains a discharge zone throughout the critical summer growing season.

The movement of ground water through the permeable material surrounding the bog was observed in a test hole (fig. 6) left uncased and unsealed just to show the fluctuations of the water table. Weekly measurements on this hole showed a 2-foot rise in water level after the heavy rains of early June, followed within a week by a 2-foot decline in water level.

The materials within the bog through which ground water flows range from medium sand and gravel to well decomposed plant material. These materials differ widely in capacity to transmit water (hydraulic conductivity). Subsurface investigations during this study and by Artist (1936) and Arnold (1969) indicate the following generalized section of organic materials at the edge of the sphagnum zone:

Material	Thickness (cm)	Thickness (in.)
Live sphagnum moss	5	2
Partially decayed sphagnum moss	5 - 15	2 - 6
Water, free	15 - 30	6 - 12
Peat (reed and sedge)	200 - 250	80 - 100
Moss peat, fibrous, decomposed	100	40

The hydraulic conductivity of similar materials measured elsewhere decreases from 10^{-2} cm/sec for the live sphagnum moss to 10^{-7} cm/sec for the decomposed moss peat (Boelter, 1965). Hydraulic conductivity of the lower sphagnum moss section at Volo Bog is about 10^{-4} cm/sec. Table 2 gives the hydraulic conductivity and storage coefficients for peat and organic soils listed in various reports.

The sand and gravel beneath the site and the sand and gravel that form the neck-like peninsula separating the three basins have a permeability of approximately 10^{-3} cm/sec. Ground-water flow through the organic materials and through the sand and gravel neck is, therefore, moderately slow.

A qualitative example of the apparent low permeability of peats was given by Burns (1905) for Michigan bogs. He observed that in one bog the greatest fluctuation in the water table occurred in the marginal sedge zone. There the water level sank from 7.2 inches above ground surface to 34.4 inches below the surface, a total drop of 41.6 inches. The fluctuation decreased toward the center of the bog: in the maple-poplar zone it was 18.4 inches; in the tamarack, 12.4 inches; in the bog shrub zone, 6.8 inches; and in the sedge mat that floats on the lake no fluctuation was observed. Burns suggested that the loose peat acted as a dam to keep the open water in the lake from flowing back to the outer zones. The distance between the open lake and the marginal sedge zone was approximately 100 feet.

Field hydraulic conductivity was measured, by methods described by Luthin and Kirkham (1949), in the upper 24 inches (61 cm) of moss peat in July 1970. The results indicated a hydraulic conductivity of about 2.5×10^{-4} cm/sec, which is approximately that reported by Boelter (1965) for partly decomposed moss peat (table 2).

Geochemistry

The geochemistry of the water in and around the bog is part of the bog ecosystem. Samples of water were taken for simple field determination of pH, alkalinity, chloride, and hardness from the upland sand and gravel, lowland sand and gravel, the gravel beneath the peat, the peat, and the open-water pond. Figure 4 shows some of the water sample points and table 3 gives the water analyses.

TABLE 2—HYDRAULIC PROPERTIES OF ORGANIC MATERIALS

Type of material	Test depth (cm)	Hydraulic conductivity (cm/sec)	Specific yield (cm/cm)	Reference
Well decomposed reed and sedge	46	1.52×10^{-7}		Sturges, 1968
		5.23×10^{-7}		
		3.02×10^{-7}		
		3.53×10^{-7}		
	91	2.16×10^{-7}		
		2.23×10^{-7}		
		1.21×10^{-7}		
Florida peat	330	1.06×10^{-4}		Colley, 1950
Fibrous peat		1×10^{-7} to 3×10^{-5}		Hanrahan, 1954
Moss peat:				
Undecomposed	15 - 25	3.81×10^{-2}	0.52	Boelter, 1965
Partly decomposed	35 - 45	1.39×10^{-4}	0.33	
Decomposed peat	45 - 60	1.11×10^{-5}	0.22	
Herbaceous peat	70 - 80	0.75×10^{-5}	0.15	
Sphagnum peat				
Partly decomposed	50 - 60	2.54×10^{-4}		This report

Waterman (1921) made quick tests of the pH of water in the substratum of the basin and found that the water under the sand and gravel upland was slightly alkaline, that in the border sedge it was neutral, and that in the floor of the tamarack forest it was moderately acidic. These observations were confirmed for Volo Bog in the summer of 1970. The alkalinity and hardness data (table 3) suggest that alkaline water enters the bog from the upland area and becomes acid as it travels upward through the organic material. Waterman (1926) suggested that the acidity of the bog water is derived from bog plants, a supposition borne out by the fact that the pond surrounded by the floating mat has the highest acidity.

The optimum acidity for sphagnum growth is about pH 5. The normal acidity of a bog mat is developed only after the dead plants begin to fill the depression. The development of acidity by the partial decomposition of the debris of the mat plants is possible only if other factors permit. Once the sphagnum moss has acidified the originally alkaline water, it continues to grow and produce more acid. The ground-water inflow is sufficiently slow to allow the moss to maintain the acid balance. Large amounts of alkaline surface water flowing into the bog could upset the balance, but the water levels are controlled by a culvert beneath Sullivan Lake Road that maintains the drainage of the surface water from the bog and prevents a backing up of alkaline water. The surface water discharge at the culvert is similar in chemical character to the upland ground water, with an alkalinity of 360 milligrams per liter (mg/l) calcium carbonate and a hardness of 480 mg/l.

Waterman (1926) also mentioned the temperature of the water in the bog as a factor in controlling plant growth. The temperature of the water in the bog and of the water in the swamp is controlled by the temperature of the ground water and the temperature of the surface water that enters the system. If large quantities of surface water were to enter during summer months, they would raise the temperature of the surface water in the bog beyond the optimum level for plant growth. Waterman (1926) pointed out that cold water from the ground-water reservoir is therefore of great importance to the development of the Illinois bogs.

TABLE 3—GEOCHEMISTRY OF THE WATER*

Sampling point (fig. 4)	Method	Depth (ft)	pH	Alkalinity gr. $CaCO_3$	Chloride (mg/l)	Hardness (mg/l)	Nitrate (mg/l)
1	Well point	28	7.9	22.5	19.1	445	8
2	Auger hole	20	6.8	24.0	7.6	462	-
3	Driven piezometer	12	---	25.0	12.4	308	-
4	Driven sampler	10	---	8.0	≈30	189	0
5	Water in pond	--	< 6	2.5	7	68	-

* Determined in the field.

HUMAN INFLUENCE ON VOLO BOG

Early Influences and Effects

Records do not show when the Volo Bog Basin was ditched for drainage. However, Waterman (1926) in the first detailed description of the basin presented the opinion that lowering the water level in the bog and adjacent depressions by ditching started a sudden increase in the growth of the floating sedge mat. He reported that long-time inhabitants of the area told him the pond occupied the entire open area within the tamarack forest when the region was first visited, about 1876, and that the quaking sedge and sphagnum mat had increased in area since that time, reducing the pond to the size he described (fig. 6). The present area of open water is approximately the same as that described in 1926.

Waterman further stated that the increased bog filling in northern Illinois in the period 1860 to 1926 was due to a permanent lowering of the water in the depressions by several feet. This lowering was probably brought about by the general clearing and draining of the area by the first European settlers. Waterman concluded that:

> A study of the maturity and climatic conditions of these bogs, as compared with those of other regions, would indicate that the sphagnum bogs of Illinois are slowly dying out in an unfavorable environment. The variation in their rate of development seems to be connected with marked changes in the water level in the depression holding the bog.

That Volo Bog water level has declined no farther since the original draining and that the bog has not been completely covered with the mat may be in part due to man's activity along the Fox River. The McHenry Dam in the Fox River Chain O' Lakes region may have prevented further draining of Volo Bog by maintaining a high water level. This dam was first built of wood in 1907 and by 1915 was replaced by a sheet-steel piling dam, which raised water level elevations upstream approximately 6 feet above the existing channel bottom. The steel dam was replaced by the existing reinforced concrete dam in 1939 (Ill. Dept. Public Works and Bldgs., 1962).

If the regional water levels had not been raised by the dam, it is possible that Volo Bog and the other Lake County bogs would have been drained or had their water levels lowered beyond the danger point for the bog flora.

Potential Effects of Future Activities

The botanical considerations of the Volo Bog controversy are beyond the scope of this report. What the effects of man's various activities would be on the vegetation of the area falls within the realm of the botanist and plant ecologist. However, considering only the effects caused by modification of geological and hydrological conditions, man could effectively destroy the water-vegetation balance in Volo Bog in two ways: by permanently draining the bog and by changing the quality and quantity of the water in the bog.

Actually, as previously discussed, the bog need not be completely drained to effectively close in the open-water zone. However, to lower the water level of the bog permanently, the outlet through Sullivan Lake Road would have to be enlarged and regraded. The level of Sullivan Lake (fig. 8) would have to remain below the 745-foot elevation during the draining. Bog water levels thus could be lowered 5 feet by gravity draining. If Sullivan Lake were lowered more than 5 feet, water from Lily Lake drain would flow back into the lake. Therefore, to drain Volo Bog, a series of pumps and lifts and well points would be necessary, with a long pipeline to transport the water out of the basin.

The water level in the bog could be lowered temporarily by installing pumps in the swamp area immediately south of the bog, and by concentrated pumping. When pumping ceased, the water level would recover, although slowly. The magnitude of the decline in water level would determine whether the level would be depressed long enough to kill the plant life.

Pollution of surface water in the bog could be initiated by increased surface runoff from increased urban development in the watershed. The conversion of pervious open land to impervious urban surfaces—such as roads, walks, streets, parking areas, shopping centers, and airports—would produce greater and more rapid runoff. The runoff would be carried by storm water drains into the part of the watershed that contains the bog and adjacent swampland and could have a harmful effect on the existing vegetation. Storm water runoff has been found in many instances to be similar to sanitary sewage in its pollution potential, and in a few instances it has been known to carry even greater amounts of some pollutants (FWPCA, 1969). Although the organic and inorganic chemical quality of storm water runoff are rather well known, the effect of these constituents on an ecological system such as that of Volo Bog are not completely predictable.

RESOURCES OF VOLO BOG AREA

Although in the past Volo Bog and portions of the adjacent areas were utilized as a nature preserve, the pressure to develop this area for other uses has been great. Conversion of the area to a suburban development has probably been the most insistently demanded use in recent years.

Of all potential uses of the bog, the extraction of resources would do the most obvious direct damage to the bog. Of the two resources present in the area—peat and deposits of sand and gravel—probably the more valuable is the acid peat in Volo Bog proper, which is composed of sphagnum and other mosses. The alkaline reed and sedge peats in the cattail swamp south of the bog also have some commercial value. Hester and Lamar (1969) described the use of peat as a resource in Illinois.

Sand and gravel is the other resource available in the immediate area. Although it is probably uneconomical and impracticable to remove sand and gravel from beneath the bog, local shallow sand and gravel deposits have been excavated just east and northeast of the bog. The same type of deposit occurs along the northeastern and eastern edges of the bog. If gravel pits were to be developed in this area and encroach upon the bog, the vegetation along the outer fringe of the bog could be physically damaged or destroyed, and the landscape along this portion of the basin would be permanently altered.

The high cost of extracting the peat or sand and gravel, along with the concern for the ecology of the bog, probably limits the Volo Bog Basin as a mineral resource area. If the bog is to be retained as a nature preserve, exploitation of these resources can be eliminated from consideration.

SUMMARY AND CONCLUSIONS

The investigation of the geology, soils, and hydrogeology has provided basic knowledge of the physical conditions of the Volo Bog Basin. The bog has been preserved for its unique botanical character, which evolved through a series of geologic and hydrologic events somewhat modified by the more recent activities of man. Continuance of the present hydrogeologic conditions within the basin would be essential to maintain the bog without further deterioration.

Study of the glacial materials revealed the sequence of lake and bog development for the past 14,000 years. The bog has undergone periods as an ice-filled depression, an open-water lake, a shallow draining lake, a lake with continually rising water levels, a swamp-surrounded lake, and finally a shallow pond surrounded by tamarack forest. The basin is a ground-water discharge point for the surrounding uplands. The alkaline ground water from the uplands is converted to acid water by the organic material in the bog. The acidic water supports the growth of swamp sumac, tamarack, and sphagnum moss, which, with other plants, are typical of acid bogs.

Drainage of large quantities of surface water into the bog from adjacent new urban developments could upset the acidity of the bog and destroy the present flora. Permanent drainage of ground water from the swamp could be accomplished only with great difficulty, but if successful it would dry up the bog and kill the flora. Short-term drainage in the swampland south of the bog would probably have a limited effect on the bog.

Extraction of peat or sand and gravel within the basin, particularly in and immediately adjacent to Volo Bog, would irrevocably alter the landscape and could permanently damage or destroy the vegetation that makes Volo Bog unique in Illinois.

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